CHAPTER 18

SANITARY WASTE SYSTEMS

18-1. General sanitary waste systems

A sanitary waste system is a system that conveys and handles sewage and excludes storm, surface, and ground water. Sewage is any liquid waste containing animal or vegetable matter in suspension or solution, including liquids containing chemicals in solution. The purpose of the sanitary waste system is to collect the waste generated at the plumbing fixtures, floor drains, and equipment drains, and to convey and dispose of this waste in an environmentally safe manner.

18-2. Sanitary waste system design features

Treatment requirements will be determined on the basis of meeting stream and effluent requirements set by either U.S. or State governments or foreign governmental agencies. Methods of treatment are grouped below.

a. Preliminary treatment. Preliminary treatment is defined as any physical or chemical process at the wastewater treatment plant that precedes primary treatment. Its function is mainly to protect subsequent treatment units and to minimize operational problems. Pretreatment at the source to render a wastewater acceptable at the domestic wastewater treatment facility is not included.

b. Primary treatment. Primary treatment is defined as physical or, at times, chemical treatment for the removal of settleable and floatable materials.

c. Secondary treatment. Secondary wastewater treatment is defined as processes that use biological and, at times, chemical treatment to accomplish substantial removal of dissolved organics and colloidal materials. Land treatment can be classified as secondary treatment only for isolated locations with restricted access and when limited to crops that are not for direct human consumption.

d. Advanced wastewater treatment. Advanced wastewater treatment is defined as that required to achieve pollutant reductions by methods other than those used in conventional treatment (sedimentation, activated sludge, trickling filter, etc.). Advanced treatment employs a number of different unit operations, including ponds, post-aeration, microstraining, filtration, carbon adsorption, membrane solids separation, and specific treatment processes such as phosphorus and nitrogen removal. This treatment is very effective in removing over 90 percent of organics and suspended solids. Low phosphorus and nitrogen can also be reached through advanced treatment.

18-3. Sanitary waste system applications

Listed below are some of the fundamental processes with their applications.

a. Preliminary. Covers neutralization, equalization, screening, grit removal, temperature adjustment, and nutrient addition.

b. Primary treatment. Covers sedimentation and dissolved-air floatation.

c. Secondary treatment. Covers activated sludge (aeration and secondary sedimentation), aerated pond w/secondary sedimentation, aerobic-anaerobic ponds, trickling filter, chemical oxidation, chemical mixing flocculation and clarification, gravity filtration, pressure filtration, dissolved-air flotation w/chemicals, and anaerobic contact.

d. Advanced wastewater treatment. Covers activated carbon adsorption, micro straining filtration, land treatment, subsurface disposal, and ground water recharge.

e. Sludge. Covers anaerobic digestion, aerobic digestion, autoclaving, elutriation, vacuum filtration, centrifugation, sand beds, presses, incineration, wet oxidation, land disposal, and sanitary landfill.

18-4. Treatment methods

Listed below are some of the methods used in waste water treatment.

a. Preliminary treatment. This includes screening, grinding, grit removal, flotation, equalization, and flocculation. Screens, grinders and grit removal are provided for the protection of other equipment in the treatment plant. Air flotation and flocculation aid in the removal of suspended solids and oil in the primary clarifier and reduce the biological loading on secondary treatment processes. Pre-chlorination or pre-aeration may be required to prevent odor problems and to eliminate septic conditions where wastewater has abnormally long runs to the plant. Equalization structures are used to dampen diurnal flow variations and to equalize flows to treatment facilities.

(1) The primary function of bar screens is protection of downstream facilities rather than effective removal of solids from the plant influent.

(2) Comminuting devices are shredders that incorporate mechanisms that cut the retained material without removing it from the sewage flow. Comminutors are generally located between grit chambers and the primary settling tanks. Each comminuting device must have a bypass for maintenance and repair purposes. The bypass will include a bar screen, described as coarse screens.

(3) The primary purpose of grit chambers is to protect pumps and other mechanical equipment. Grit chambers will be located ahead of pumps and comminuting devices.

(4) Dissolved air flotation is a unit process whereby particulate matter is separated from a wastewater, causing the matter to float to the liquid surface.

(5) Flocculation units will be used and will immediately precede clarification units when a chemical precipitation process is employed as part of primary, secondary, or advanced wastewater treatment schemes.

(6) Dissolved air flotation is a unit process whereby particulate matter is separated from a wastewater, causing the matter to float to the liquid surface.

b. Primary treatment. The purpose of primary treatment is to remove solids that are not removed during preliminary treatment. Processes that provide primary treatment are primary sedimentation (clarification) and Imhoff tanks. In most facilities, primary treatment is used as a preliminary step ahead of biological treatment.

(1) Sedimentation tanks allow solids to drop out of the wastewater. They usually take two forms. One is the rectangular tank with a minimum length of flow from inlet to outlet of 10 feet in order to prevent short circuiting of flow in the tank. In existing installations, tank length-to-width ratio varies between 3:1 and 5:1. Tanks will be designed with a minimum depth of 7 feet except final tanks in activated sludge plants, which will be designed with a 9-foot minimum depth. The other tank type is the circular tank. Circular tank diameters range from 25 to 150 feet. Side-water depths are 7 feet as a minimum, and tank floors are deeper at the center. A circular sludge-removal mechanism with peripheral speeds of 5 to 8 feet per minute will be provided for sludge collection at the center of the tank. Chemical precipitation may be introduced at this point to alleviate problems such as phosphorous, odor, industrial waste, or plant overload.

(2) Imhoff tanks provide removal of settleable solids and the anaerobic digestion of these solids in the same unit. They are two-level structures that allow the solids to settle out in the upper level. The settled solids then fall through slots into the lower level where they undergo digestion. The gas produced during digestion escapes through the vent areas along the sides of the upper level.

c. Secondary treatment. Secondary treatment is the use of secondary sedimentation tanks to allow the biological solids in the wastewater leaving the trickling filter to settle out. This produces an effluent for discharge, and the settled solids can be recirculated to the trickling filter to enhance its performance.

18-5. Typical sanitary waste systems

The following systems are used at the sites for waste treatment.

a. Trickling filter process. These have been justified by their low initial cost, low operating and maintenance costs, and relative simplicity of operation. Although the effluent from trickling filter plants of earlier design was of poorer quality than that from activated sludge plants, the performance of trickling filters designed more recently is comparable to that of activated sludge plants. Both processes offer certain advantages, with trickling filters providing good performance with minimal operator care and few, if any, energy requirements. An example of a typical trickling filter treatment process appears in figure 18-1. Although not shown, dual or parallel trains are appropriate for all treatment systems having a design capacity rating equal to or greater than 0.5 million gallons per day.

b. Activated sludge process. The activated sludge process is capable of meeting secondary treatment effluent limits. All designed processes will include preliminary treatment consisting of bar screen as a minimum and, as needed, comminutor, grit chamber, and oil and grease removal units. In a conventional (plug-flow) activated sludge plant (figure 18-2), the primary-treated wastewater and acclimated micro-organisms (activated sludge or biomass) are aerated in a basin or tank. After a sufficient aeration period, the flocculent activated sludge solids are separated from the wastewater in a secondary clarifier. The clarified wastewater flows forward for further treatment or discharge. A portion of the clarifier underflow sludge is returned to the aeration basin for mixing with the primary-treated influent to the basin and the remaining sludge is wasted to the sludge handling portion of the treatment plant.

c. Stabilization pond process. A wastewater stabilization pond is a relatively shallow body of wastewater contained in an earthen basin that is designed to treat wastewater. ("Oxidation pond" is a synonymous term.) They are used to treat a variety of wastewater's, from domestic wastewater to complex industrial waters, and they function under a wide range of weather conditions, i.e., tropical to arctic. Ponds can be used alone or in combination with other treatment processes. If sufficient land is available, ponds are a cost-effective means to provide wastewater treatment. In addition, their operation is easy and their maintenance requirements are minimal. Below are listed the different types of ponds.

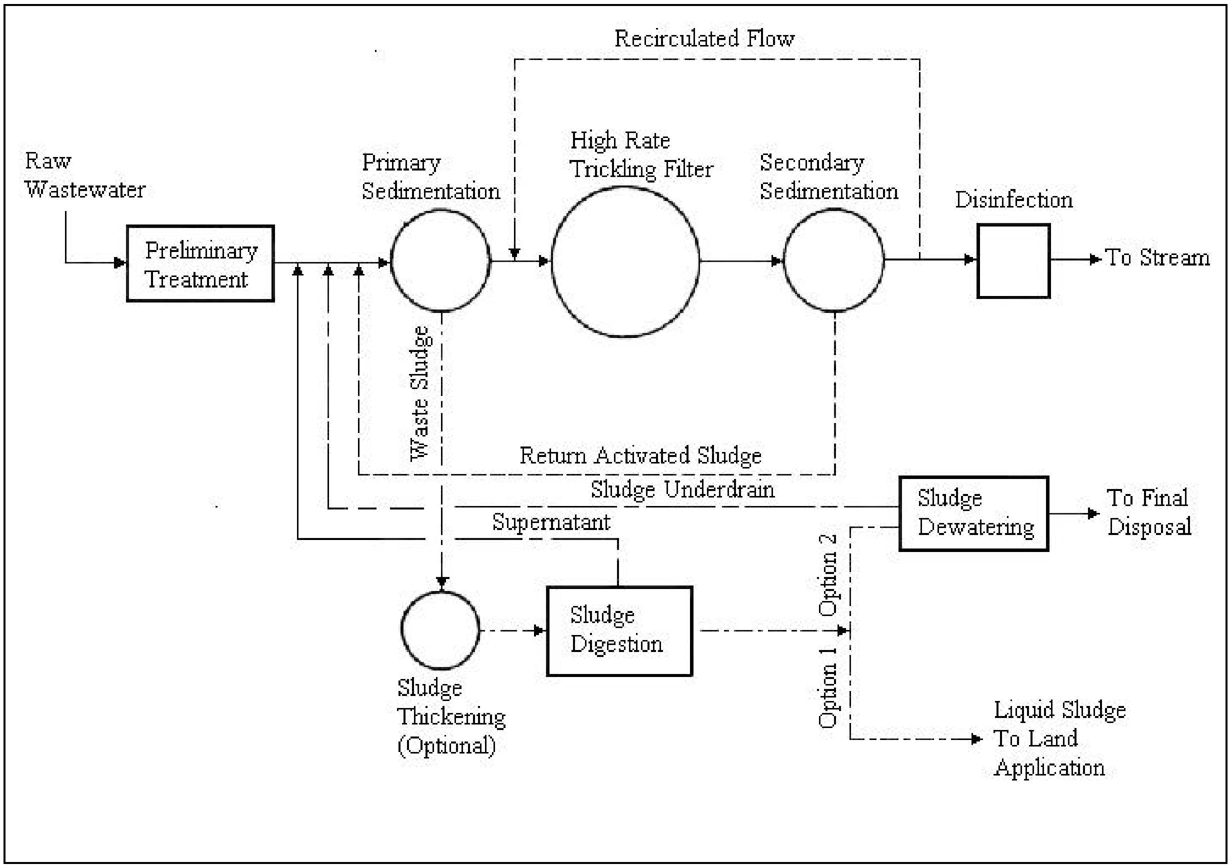

Figure 18-1. Typical trickling filter process treatment train

(1) An aerobic stabilization pond contains bacteria and algae in suspension; aerobic conditions (the presence of dissolved oxygen) prevail throughout its depth. There are two types of aerobic ponds:

(a) Shallow oxidation ponds obtain their dissolved oxygen via two phenomena: oxygen transfer between air and water surface, and oxygen produced by photosynthetic algae.

(b) An aerated pond is similar to an oxidation pond except that it is deeper and mechanical aeration devices are used to transfer oxygen into the wastewater.

(2) Three zones exist in an aerobic-anaerobic pond. They are the following.

(a) A surface zone where aerobic bacteria and algae exist in a symbiotic relationship;

(b) An anaerobic bottom zone in which accumulated solids are actively decomposed by anaerobic bacteria; and

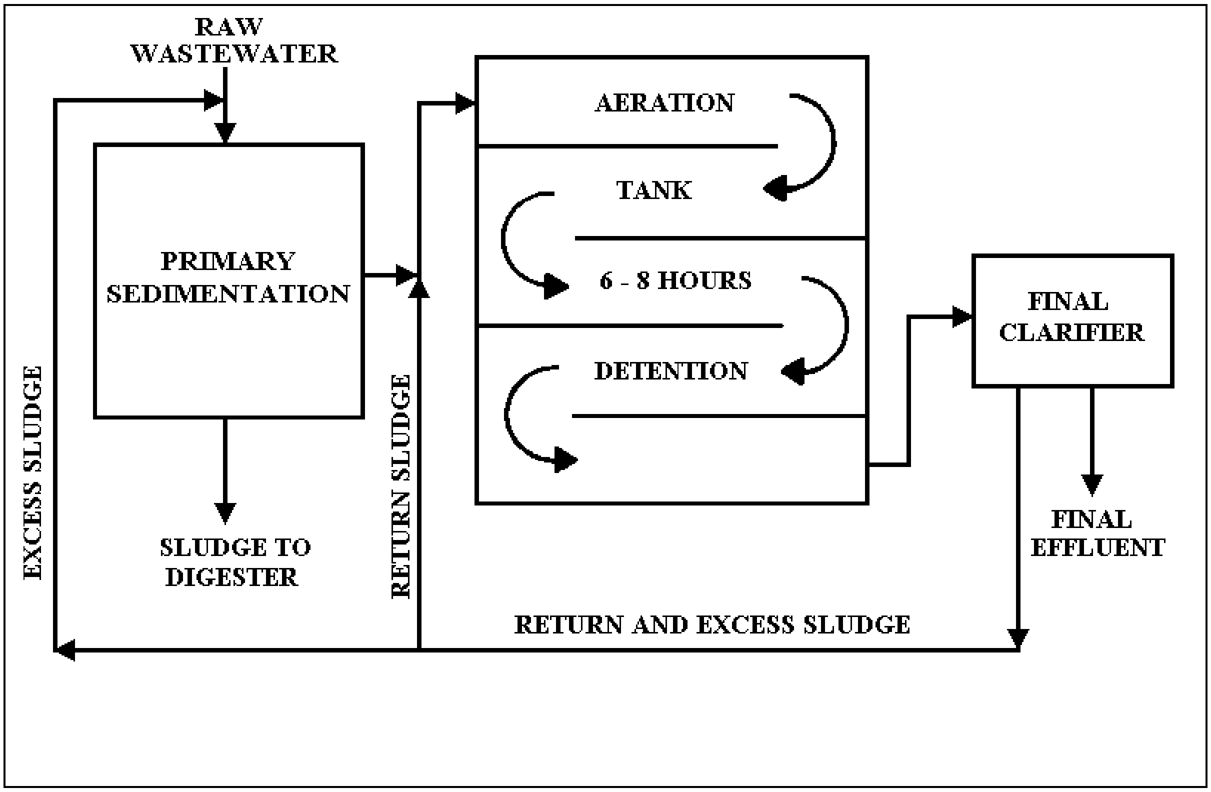

Figure 18-2. Conventional plug flow activated sludge flow diagram

(c) An intermediate zone that is partly aerobic and partly anaerobic in which the decomposition of organic wastes is carried out by facultative bacteria. In these ponds, the suspended solids in the wastewater are allowed to settle to the bottom. As a result, the presence of algae is not required. The maintenance of the aerobic zone serves to minimize odor problems because many of the liquid and gaseous anaerobic decomposition products, carried to the surface by mixing currents, are utilized by the aerobic organisms.

(3) Controlled discharge ponds have long hydraulic detention times and effluent is discharged when receiving water quality will not be adversely affected by the discharge. Controlled discharge ponds are designed to hold the wastewater until the effluent and receiving water quality are compatible.

(4) Complete retention ponds rely on evaporation and/or percolation to reduce the liquid volume at a rate equal to or greater than the influent accumulation.

d. Advanced wastewater treatment processes. A number of different unit operations are used in various configurations to make up an advanced wastewater treatment system. There are no advanced wastewater treatment process trains that can be considered typical or most applicable to a C4ISR installation. Effluent quality standards exceeding established secondary treatment level standards will dictate the advanced treatment unit processes and their combinations that will provide the necessary degree of treatment. Unit operations typically used in advanced treatment are presented below.

(1) Wastewater treatment ponds may be used as a practical and economical method for upgrading existing secondary treatment facilities to obtain improved organic and suspended solids removal. Both aerobic and aerobic-anaerobic ponds can be used for this purpose. Ponds used for polishing purposes are subject to the same operating characteristics as those used for primary or secondary treatment, and the same precautionary design considerations must be applied.

(2) Post-aeration can be accomplished by diffused, cascade, U-tube, or mechanical aeration. Diffused aeration is carried out in tanks 9 to 15 feet deep and 10 to 50 feet wide (depth-to-width ratio is maintained at less than 2), with detention time of about 20 minutes. The maximum air requirement is approximately 0.15 cubic feet per gallon of wastewater treated. Mechanically aerated basins are 8 feet deep and require 15 to 50 square feet per aerator. The drop required for cascade aeration in a stepped-weir structure or in a rapidly sloping channel filled with large rocks or concrete blocks will depend on the desired oxygen uptake: 2 feet of drop will be provided for each milligram per liter of dissolved oxygen increase required.

(3) A microstrainer consists of a rotating drum supporting a very fine, stainless steel or plastic screen. Wastewater is fed into the inside of the drum and filters radially outward through the screen, with the mat of solids accumulating on the screen inside the drum. The solids are flushed into a removal trough at the top of the drum by a pressurized backwash system. From this trough, the solids are returned to the head of the system. Process effluent wastewater can be used for the backwash.

(4) The function of filtration is to remove as much of the suspended solids in the waste stream as possible through the use of filters. A filter consists of various sizes of media bounded by a container. Media in this case consists typically of different grades of sand, gravel, anthracite coal, etc. The effectiveness is derived from the type and size of filter media, depth of filter, amount of backwash, chemical pretreatment dosage, and filter rate and duration.

(*5)* Activated carbon adsorption beds can provide filtration but their primary function is to remove non-biodegradable organics, taste and odor compounds, and reduce color in the waste stream.

(6) Mineral addition and lime addition are the principal methods for in-plant removal of phosphorus from wastewater. The most commonly used of these metal salts are: alum, a hydrated aluminum sulfate, sodium aluminate, ferric sulfate, ferrous sulfate, ferric chloride, and ferrous chloride. Mineral addition is usually followed by anionic polymer addition, which aids flocculation; the pH may require adjustment depending on the particular process. In lime addition, phosphorus removal is attained through the chemical precipitation of hydroxyapatite. Addition can take place at the primary or secondary treatment stage.

(7) Land application systems are the use of land and biomass growth as a wastewater treatment area. Because land treatment of wastewater entails a higher risk than other treatment processes of introducing pathogenic micro-organisms and toxic chemicals into groundwater and surface water, land treatment system design must carefully consider all possible means to prevent water supply contamination.

(8) Soil biota are capable of stabilizing most organic wastes, including oily sludges. Today, only about 25 percent of sludges are spread on land; even less is composted. However, the organic materials in sludges are beneficial in restoring fertility to soils disturbed by mining, gravel operations, or poor

agricultural practices. There are, however, some major limitations. Concentrated sludges (if not composted or otherwise stabilized) placed on land should be immediately covered to prevent odor production and insect breeding. Sludges can be sliced or injected into soil or into stubble, using special equipment. Deep snow and deep frost will stop land spreading operations.

(9) Nitrification occurs in two steps: first NH is converted by Nitrosomonas bacteria; then converted by Nitrobacter bacteria. This process is limited by the relatively slow growth rate of Nitrosomonas.

(10) Denitrification is performed by heterotrophic anaerobic organisms and, therefore, requires an organic carbon source and anaerobic conditions. Suspended growth denitrification will provide gentle mixing (no aeration) with the mixed liquor being clarified. The effluent is aerated to provide dissolved oxygen and to drive off entrained nitrogen, and the sludge is recycled to the contact tank.

(11) Three-stage biological systems. Three-stage biological systems are essentially a combination of separate stage nitrification and denitrification. The advantage of this system is its flexibility of operation and the main disadvantage is the capital cost involved. This configuration also works to prevent short circuiting, which can be a problem in nitrification-denitrification when plug flow is not achieved.

(12) In anaerobic contact process, a further development of the high-rate digestion process allows separation and recycling of digested sludge solids. Like the activated sludge process, detention and mean cell residence times are controlled. Denitrification within these contact vessels approached 95 percent.

e. Small installations. Septic tanks, biological package treatment plants, and stabilization ponds are cost effective and require less operational and maintenance attention than other treatment options. Therefore, these treatment methods are especially applicable to C4ISR installations having design capacities of less than 100,000 gallons per day. See figures 18-3 through 18-6 for depictions of a septic tank, lift station, sewage ejector, and valves associated with these installations.

18-6. Sludge handling, treatment, and disposal

Sludge, or residual solids, is the end product of wastewater treatment, whether biological or physical/chemical treatment. Primary sludge is from 3 to 6 percent solids. Treatment objectives are reduction of the sludge and volume, rendering it suitable for ultimate disposal. Secondary objectives are to utilize the generated gas if anaerobic digestion is selected as part of the sludge management strategy. In addition, an attempt should be made to sell/utilize the sludge as a soil conditioner rather than paying to dispose of it.

18-7. Disinfection

Disinfection is a process in which pathogenic organisms are destroyed or inactivated. This process may be accomplished by physiochemical treatment or addition of chemical reagents. Improved coliform and virus removal can be obtained by utilizing flash mixing and acid feed for pH reduction. Chlorine, as liquid chlorine or in the form of chlorine compounds, is the most common chemical used to disinfect wastewater treatment plant effluents. Calcium hypochlorite or sodium hypochlorite will only be used as chlorinating agents for very small installations (less than 20,000 gallons per day). Ozone has been an effective disinfectant when used in the water treatment field, and its use as a disinfectant for wastewater is being seriously considered. This interest has developed mainly because zonated effluents have normally shown no toxic effects on the receiving water biota as have residual chlorine compounds; however, for certain industrial wastes, epoxides have been found. The major disadvantage of ozonation is the high capital and operational cost associated with its generation.

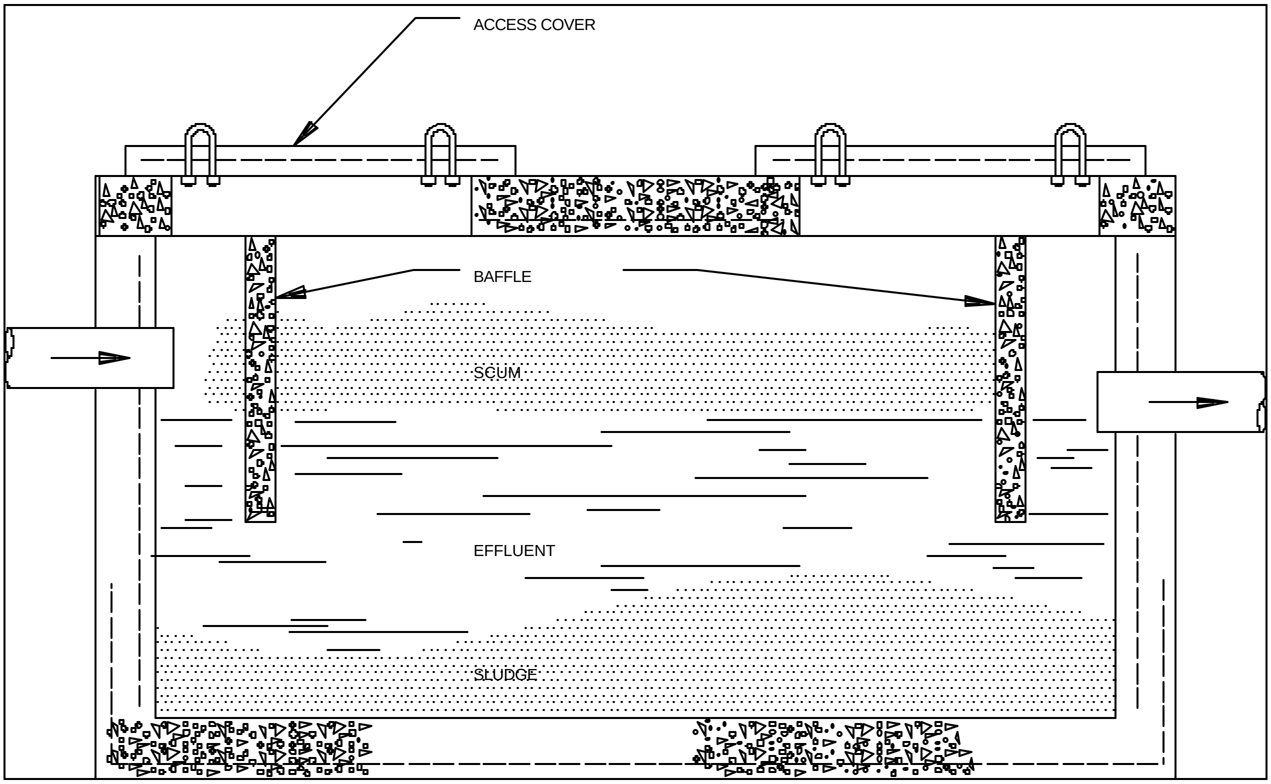

Figure 18-3. Septic tank

18-8. Flow measurement, sampling, and process control

Monitoring is required by Environmental Protection Agency (EPA) when National Pollutant Discharge Elimination System (NPDES) permits are issued to assure compliance with the permit. Additionally, certain operational monitoring is required to ensure that proper treatment plant performance is maintained. Below is a listing of the instrumentation used.

a. Continuous recording of flow. Wastewater flow rates will be monitored and recorded for purposes of evaluating treatment plant performance and will also be used when treatment changes are involved. Continuous flow measurement is necessary in order to monitor diurnal variations in flow which may affect treatment plant efficiency. Flow rates must also be taken into account when sampling wastewater quality.

b. Types of flow measuring devices. The following paragraphs describe the types that are suitable for use in wastewater treatment plants.

(1) Venturi meters are not to be used for measuring wastewater or sludge flow unless sufficient hydraulic head is available, or unless the Venturi tube is so constructed as to prevent solids accumulation at the upstream side of the throat. Clogging of the pressure tubes is avoided by providing cleanout taps and discharging a stream of fresh water through them into the sewer. Positive separation of potable water supply from this connection must be assured.

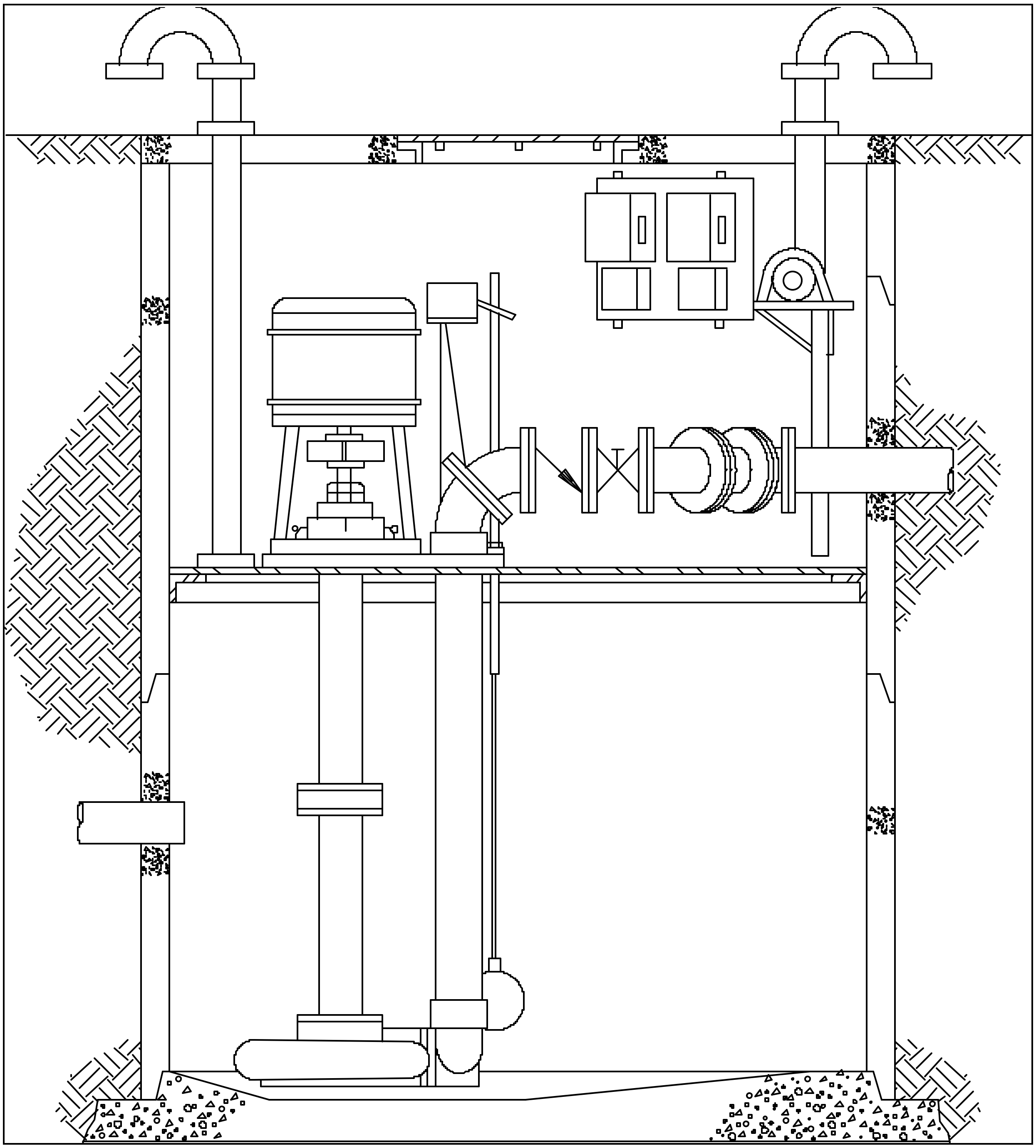

Figure 18-4. Lift station with wet pit vertical centrifugal pump

(2) Weirs will be located in a channel so that the flow will not be disturbed by turbulence and in such a manner that the depth of flow over the weir can be observed and recorded. When continuous recording is required, the float will be installed in a chamber separated from the main channel of flow but connected thereto by piping.

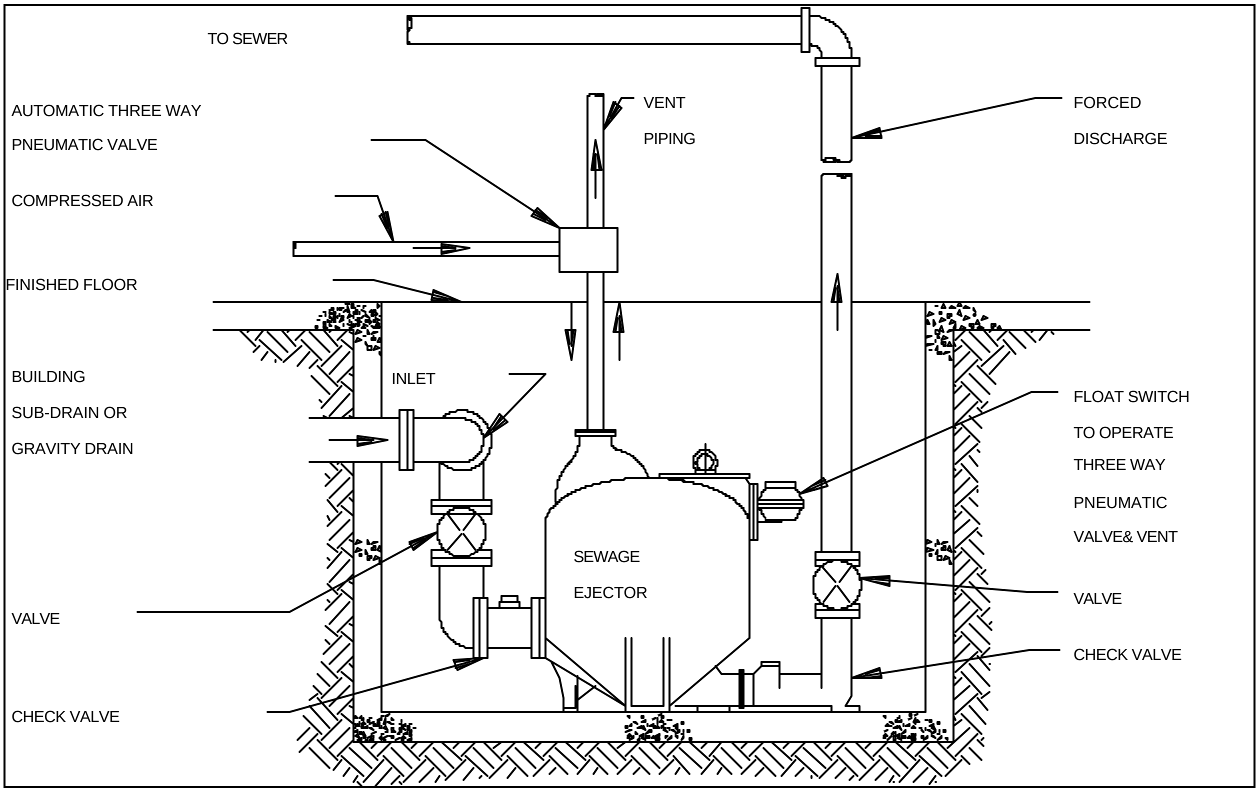

Figure 18-5. Pneumatic sewage ejector

(3) Parshall flumes have many advantages: the loss of head is minimal; it is self-cleaning; flow measurement can be made in open-channel flow; and it has no moving parts to malfunction. The downstream water-surface elevation above the flume approach floor must not exceed 65 percent of water elevation upstream of the flume. The flume will be designed with the narrowest throat practicable for the conditions under consideration. This is particularly important where a Parshall flume is utilized to control the velocity through a grit chamber.

(4) Magnetic flow meters can be used for flow measurement in wastewater treatment plants. There are many types of magnetic flow meters, however, and direct contact with the manufacturers is the quickest and generally most practical way to determine their application to specific wastewater measurements.

(5) Ultrasonic devices are being used to measure levels in Parshall flumes. A pulsing signal is bounced to the receiver where the level is related to the time elapsed. Since no components are in contact with the liquid, this device is applicable to many types of wastes and situations.

c. Sampling. Wastewater sampling at various points in the sewage treatment process is useful in evaluating operation efficiency. This can be used internally to optimize the process and is also used by regulatory agencies to judge whether treatment plant regulations are satisfied. Sampling is also used to establish changes when treating industrial wastes. Provisions for sampling sites must be made in the plant design. The type of sampling provisions (flow proportional, composite, or grab-sample collection) will be dictated by the type of sampling required in any discharge permit. Forward flow, recycled flow, sludge flow, chlorine residual, pH and dissolved oxygen are some of the process control parameters that can be monitored on a continuous basis.

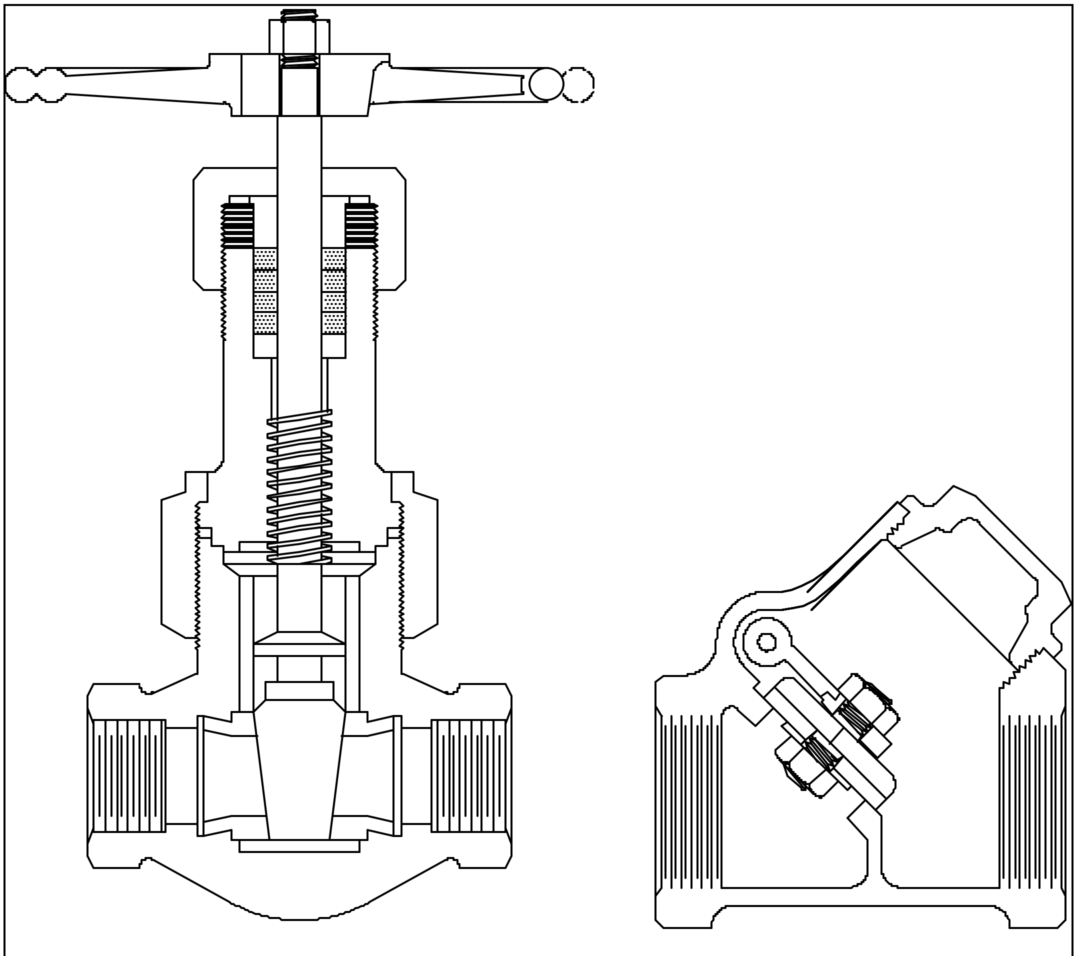

Figure 18-6. Gate valve and swing check valve

d. Monitoring equipment for process control. Monitoring equipment will be used to indicate and/or record flow quantities and, if justified, pressure, temperature, liquid levels, velocities, and various quality parameters such as dissolved oxygen, biochemical oxygen demand, total suspended solids, ammonia, nitrate, and pH.

(1) In sewage pumping stations, flow measurement is necessary to control periodic pump operation. Watt-hour meters and pump-time meters will be used to ensure uniform pump wear in multiple-pump installations.

(2) Monitoring primary treatment processes will require only flow measurement and recording and perhaps grit level monitoring. When digestion of the primary sludge follows, raw sludge flow rates must be monitored and controlled. In digestion, gas flow rates, tank pressures, and sludge temperatures will be monitored, and digester operation adjusted accordingly.

(3) Trickling filter monitoring will include flow measurement of influent, effluent and recirculation lines, and also volume of sludge pumped to or from the digesters. These parameters are used in determining and controlling hydraulic and organic loading as well as in controlling settling tank efficiencies. Activated sludge treatment will require the same monitoring with the addition of mixed-liquor, volatile suspended solids, and air supply monitoring.

(4) In sludge elutriation, sludge and elutriant flows will be measured in order to determine required sludge conditioner quantities. Sludge filtration will require measurements and control of sludge and sludge-cake flows and chemical feed rates. All chemical feed lines will be monitored and controlled, whatever their function. Sludge incineration and drying processes will require temperature monitoring at various points, pressure gauges, and sludge weighing equipment. Fuel flow rates, whether waste gas or auxiliary fuel, must be measured and controlled.